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of earthquakes, build the biggest telescope in the world, and in addition anticipate black holes, but John Michell did. Needless to say, he did not succeed in all these efforts, but the extent of his ambition is astonishing, especially since he would be paying for these efforts from his own modest income.

In *Weighing the World*, Russell McCormach has given us a very complete biography of this extraordinary but little known individual. In addition to a description of Michell's scientific efforts, McCormach describes the cultural background of his life: his education at Queen's College, Cambridge; his life as a fellow at Queen's; his ascent in the Church through a series of livings, assisted by his patron Sir George Savile, finally settling at Thornhill in Yorkshire. Tracking Michell's life cannot have been easy. McCormach adds in an appendix all forty-four of Michell's known letters. Apparently Michell did not write a letter unless he had something significant to report; then he would often write at length. Much of his correspondence was with Henry Cavendish, who, after Michell's death, acquired his torsion balance and completed the task of measuring the force of gravity directly. Another correspondent and visitor at Thornhill was William Herschel, who succeeded where Michell failed in grinding a mirror for his great telescope. Michell's proposed telescope had a large aperture and a short focal length to maximize the brightness of the image, but, as with most such efforts in the eighteenth century, his mirrors cracked during grinding. Herschel bought Michell's mirror after his death because of the excellence of its alloy and the ingenuity of its mounting.

Michell was a "natural philosopher," which meant that he held the entire natural world as his subject of study. He had greater mathematical skill than many of his fellow philosophers and tended toward fields of study, such as astronomy, that required mathematical calculation, but he was also an enthusiastic experimenter. He eschewed the most exciting subjects of his time, electricity and heat, because he believed these fields of research were too crowded. We find him helping Joseph Priestley resolve mathematical problems. He assisted his friend, John Smeaton, with English grammar, since Smeaton's practical use of the language did not appeal to the Royal Society. Smeaton also asked Michell what he should call his profession. He thought the word "engineer" should be reserved for the actual operators of engines and suggested "engineery" as an appropriate alternative. Smeaton, finally and fortunately, settled on "civil engineer" to distinguish himself and his cohorts

from military engineers. Although the letters are few, Michell's contacts were important. He was welcome at the London clubs associated with the Royal Society, where the members competed to have him as their guest. He was a complete Newtonian. One reason for weighing the earth was to determine the masses of other heavenly bodies. He speculated that a star might have sufficient gravity to prevent light particles from escaping its force field, thus creating a Newtonian "black hole." Scientific imagination of this magnitude is rare. This fine biography gives us entry into the life of an extraordinary individual.

THOMAS L. HANKINS

**John C. Powers.** *Inventing Chemistry: Herman Boerhaave and the Reform of the Chemical Arts.* viii + 260 pp., app., bibl., index. Chicago/London: University of Chicago Press, 2012.

Among historians of science and medicine it is well known that the Dutch medical teacher Herman Boerhaave was the "teacher of Europe," turning the early eighteenth-century Leiden medical faculty into the contemporary center of medical excellence. In the past decade historians have argued that Boerhaave's pedagogical success was based on the idea that students had to *understand* medicine. This meant that, rather than teaching standard prescriptions and cures, Boerhaave always encouraged his students to find out *for themselves* what nature did and how it aided the practice of medicine. So, rather than slavishly following a specific medical handbook, Boerhaave always told his students to experiment themselves, to think about the causes of diseases and to invent new cures. At the same time, he adopted chemistry as an important basis for medicine, since chemistry, in his view, offered the best strategies for investigating the hidden properties of natural bodies.

In *Inventing Chemistry* John Powers elaborates on this argument, stating that Boerhaave transformed the old "chymistry"—essentially an artisanal practice based on alchemy and the ideas of Paracelsus—into "chemistry"—an experimental philosophical discipline directed at the making of theoretical knowledge. Powers has structured his argument around two defining characteristics of Boerhaave's system: Boerhaave's instrument theory as a novel way of understanding chemical action; and the philosophical rhetoric that he followed in order to systematize his investigations into nature.

Powers argues that Boerhaave no longer believed that chemists should extract the funda-

mental principles (such as salt, sulfur, and mercury) from bodies (as was customary at the time). Instead, he employed what Powers calls an instrument theory as an alternative approach to understanding chemical operations. He defined the classical elements fire, air, water, and earth (and menstruums) in terms of instruments acting on natural bodies in order to reveal their latent properties. Thus, the instrument theory focused on what was formerly taken for granted (and neglected): the effects generated and the properties revealed during a chemical operation. Powers suggests that Boerhaave used the chemical instruments as pedagogical tools around which he organized and discussed chemical phenomena.

Moreover, the instrument theory was central to what Powers calls Boerhaave's *scientia* of chemistry. Here Powers refers to Peter Shaw's definition of Boerhaave's *Elementa chemiae* as "the first textbook of philosophical chemistry." The label "philosophical" serves to illuminate that Boerhaave set up his textbook according to a fixed pedagogical rhetoric and that he subjected his practical method of discovery to the same theoretical principles. So Powers maintains that Boerhaave's approach was "essentially academic" and that his chemical practice was always guided by and in aid of chemical theory.

Basing his work (in part) on his study of the difficult-to-access Boerhaave manuscripts kept in the military academy in St. Petersburg, Powers also offers an analysis of Boerhaave's views of alchemy, including a presentation of his alchemical experiments on mercury in a similar theory-dominant framework. In rich detail, Powers describes how Boerhaave became very skeptical about transmutational alchemy: he no longer believed it possible to change base metals into gold or to make the philosopher's stone.

How should we situate Powers's arguments both historically and historiographically? His major contribution entails a deepening of existing arguments in service of linking the various aspects of Boerhaave's theoretical perspectives to his pedagogy. For instance, Powers's in-depth discussion of Boerhaave's chemistry as grounded in an instrument theory reflects the argument previously made by Rosaleen Love in her 1974 article on Boerhaave's element-instrument. Love argued in her article that Boerhaave considered the four classical elements as instruments of chemical and physical changes and not, as was customary at the time, as the building blocks of matter that defined its properties. Similarly, though elaborated through an analysis of Boerhaave's St. Petersburg manuscripts, Powers's conclusions on Boer-

haave's alchemy confirm rather than counter what other historians have argued.

Another question is how Powers's theory-dominant view fits with the current historiography of chemical practices and materials. Ursula Klein has recently argued that Boerhaave abolished the traditional dichotomy between the hand and the mind and that most of his contemporary fame was based on the "practical" (and not the theoretical) part of his textbook. In fact, Boerhaave educated very few experimental philosophers, especially as compared to the many practicing doctors who graduated from his courses. Moreover, Powers's argument seems to contradict Boerhaave's aversion to general laws and theories. Boerhaave always emphasized the importance of understanding the basic principles of chemistry and medicine, not for the purpose of theorizing about diseases or chemical reactions, but in order to try out new things *in practice*.

If Powers had taken the new historiography of material and knowledge production more seriously, he would perhaps have come to a different and much more exciting picture of Boerhaave. Take the instrument theory: Rather than looking at how Boerhaave philosophically and rhetorically employed the chemical instruments as pedagogical (theoretical) tools, he could have looked at how Boerhaave employed them in practice and how this incited new ideas on the latent properties of bodies. Boerhaave might then be understood as a "hands-on" experimenter whose pedagogy stood perhaps far closer to the teaching of his famous contemporary Georg Ernst Stahl than Powers and other historians have led us to believe.

This, however, would have been a different book, and it is perhaps not fair to criticize Powers for not writing it. *Inventing Chemistry* is valuable in details. It is perhaps not novel on all counts, but it will still help the reader understand why Boerhaave was the early eighteenth-century Nestor of academic teaching.

RINA KNOEFF

**George Rousseau.** *The Notorious Sir John Hill: The Man Destroyed by Ambition in the Era of Celebrity*. xxxi + 391 pp., illus., apps., bibl., index. Bethlehem, Pa.: Lehigh University Press, 2012. \$90 (cloth).

George Rousseau has long been on John Hill's trail, having previously published *The Letters and Papers of Sir John Hill* (AMS Press, 1982). Hill (1714–1775) is best known to historians of science as a mid-eighteenth-century critic of the